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Review

The Use of Constructed Wetland for Mitigating Nitrogen and Phosphorus from Agricultural Runoff: A Review

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Abstract: The loss of nitrogen and phosphate fertilizers in agricultural runoff is a global environmental problem, attracting worldwide attention. In the last decades, the constructed wetland has been increasingly used for mitigating the loss of nitrogen and phosphate from agricultural runoff, while the substrate, plants, and wetland structure design remain far from clearly understood. In this paper, the optimum substrates and plant species were identified by reviewing their treatment capacity from the related studies. Specifically, the top three suitable substrates are gravel, zeolite, and slag. In terms of the plant species, emergent plants are the most widely used in the constructed wetlands. *Eleocharis dulcis*, *Typha orientalis*, and *Scirpus validus* are the top three optimum emergent plant species. Submerged plants (*Hydrilla verticillata*, *Ceratophyllum demersum*, and *Vallisneria spiralis*), free-floating plants (*Eichhornia crassipes* and *Lemna minor*), and floating-leaved plants (*Nymphaea tetragona* and *Trapa bispinosa*) are also promoted. Moreover, the site selection methods for constructed wetland were put forward. Because the existing research results have not reached an agreement on the controversial issue, more studies are still needed to draw a clear conclusion of effective structure design of constructed wetlands. This review has provided some recommendations for substrate, plant species, and site selections for the constructed wetlands to reduce nutrients from agricultural runoff.

Keywords: construction wetland; substrates; plants; site selection

1. Nitrogen and Phosphorus in Agricultural Runoff

Nitrogen (N) and phosphorus (P) are the main pollutants in agricultural runoff, contributing to the diffused pollution. Hazards caused by N and P residues in agricultural runoff have posed serious threats to the sustainable development of many countries, particularly the developing countries [1,2]. Excessive N and P from agricultural runoff can pollute the environment [3,4], cause algae bloom [5,6], disturb fisheries and tourism [7–9], and threaten water safety [10–12].

It is very challenging to consistently reduce the use of N and P fertilizers to protect the agroecosystems [13,14] because world grain production still largely depends on N and

P fertilizers [15,16]. Farmers often overuse fertilizers to pursue high crop yield [17,18]. Therefore, fertilizer use has been increasing continuously at a growth rate of around 5% per year [19]. However, only 30%–35% of N and 10%–20% of P are absorbed by crops, and the majorities are lost along with the agricultural runoff, exacerbating the diffused pollution [20]. Currently, excessive N and P retention in the aquatic environment has become a worldwide environmental problem [21], and it is vital and urgent to find an effective solution to mitigate N and P from agricultural runoff.

Some countries have started to take some measures to limit the total consumption of chemical fertilizers to mitigate the environmental damages [22,23], but pollution from overuse fertilizers has been a chronic problem [24]. Because of the characteristics of diffusion, N and P in agricultural runoff need to be treated in large areas and specific locations [25]. Ecological engineering is one of the main approaches to control agricultural diffused pollution, including source control and process weakening [26]. Compared with source control, process weakening is a more widely used methodology. Process weakening refers to the process of intercepting pollutants and recycling by constructing ecological facilities. Constructed wetland is one of the widely used approaches for process weakening. Therefore, it is of great significance to review comprehensively the documents related to the removal of N and P using the constructed wetland.

The main aims of this review are to (i) identify the optimum substrates and plant species of constructed wetland for mitigating N and P from agricultural runoff, (ii) elucidate the site selection of constructed wetland based on Geographic Information System (GIS) technology, and (iii) sort out the relations of wetland constructional structure and the mitigating performances of N and P in agricultural runoff. In addition to the perspectives of economic feasibility, regional suitability, and environmental sustainability, this article reviewed the substrates and plant performances, technical methods of site selection, and structural designs to mitigate N and P from agricultural runoff. The abstract picture of the review is shown in Figure 1.

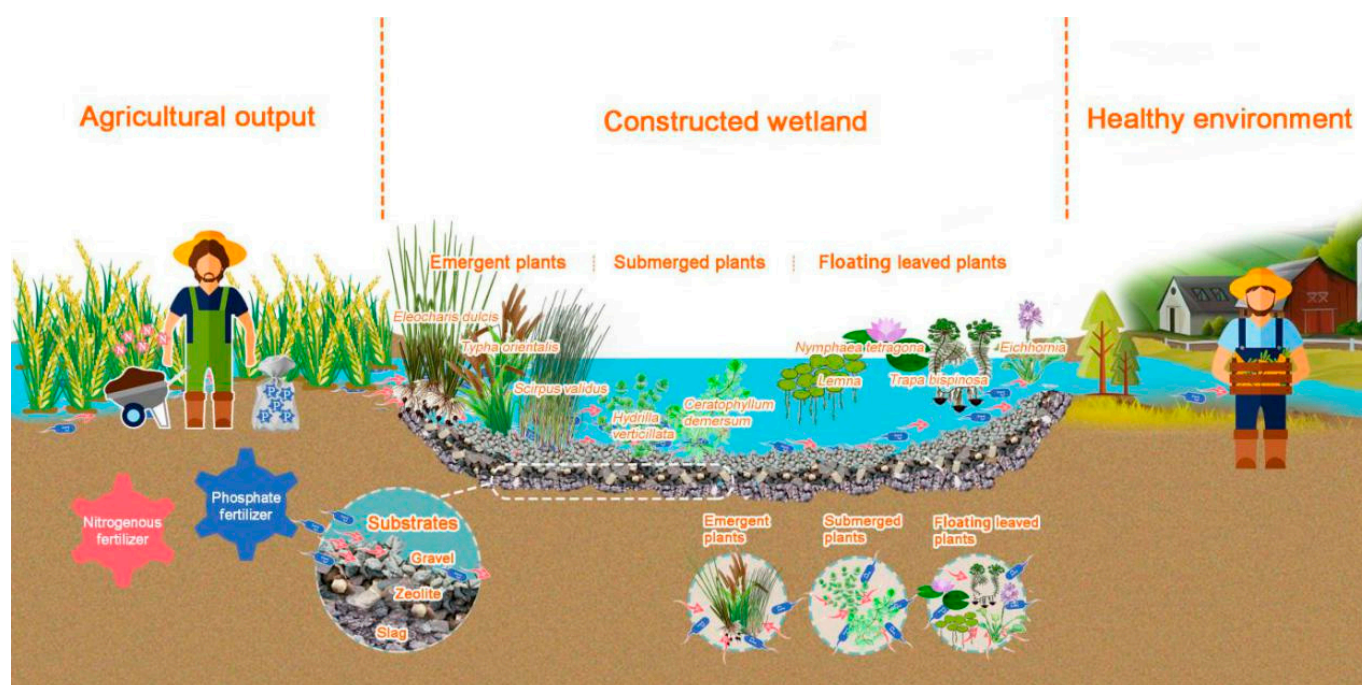


Figure 1. Graphical abstract of constructed wetland mitigating N and P from agricultural runoff.

2. Optimum Substrates and Plants of Constructed Wetland to Mitigate Nitrogen and Phosphorus

Constructed wetland is an artificial coordinated system composed of substrate, plant, microorganism, and soil [27]. In the last decade, it has played an increasingly important

role in the treatment of urban domestic sewage, industrial sewage, and agricultural wastewater [28–30]. In general, constructed wetlands can be divided into three types—surface flow, subsurface flow, and vertical flow constructed wetlands [28,31]. Purification capacities of different types of constructed wetland vary greatly, especially for the specific pollutants. Pollutant removal by the constructed wetland involves several processes, including sedimentation, photolysis, hydrolysis, microbial degradation, adsorption, degradation, and plant uptake. However, it is difficult to separate the individual process clearly because it is a complex process [32] and also due to its interactions with other pollutants [33].

In terms of N and P removal, N removal is related to the processes of ammonification, nitrification, plant absorption, and ammonia adsorption [34], and P removal is achieved through the combination of substrates, plants, and microorganisms [28]. For the ecological benefits of constructed wetlands, scholars have conducted many studies, but most studies are theoretical studies at the laboratory, posing a shortcoming in the practical application.

2.1. Substrates' Identification for Mitigating Nitrogen and Phosphorus from Agricultural Runoff

Substrate plays an important role in the mitigation of N and P. The commonly used substrates are generally divided into three types—natural materials, industrial by-products, and manufactured products.

Various substrates have been used in the constructed wetlands, including gravel, clay, marble, bentonite, limestone, shale, wollastonite, zeolite, sand, calcite, vermiculite, dolomite, shell, peat, maerl, activated carbon, compost, ceramsite, lightweight aggregate, calcium silicate hydrate, coal cinder, fly ash, slag, hollow brick crumbs, wollastonite tailing, alum sludge, Moleanos limestone, oil palm shell, and others. Table 1 summarizes the characteristics, including both advantages and disadvantages, of ever-used substrates.

Table 1. Characteristics of substrates used in the constructed wetland.

Type of substrates	Characteristics	References
Natural material		
Gravel	Widespread and common; good adsorption; low cost; phosphorus and nitrate removal is not good.	[35]
Clay	Plentiful and cheap; excellent effect, green environmental protection; high adsorption of organic compounds; low removal rate of COD, NH ₃ -N, and TN.	[36]
Marble	High removal ability of phosphorus and ammonia nitrogen; economic accessibility; susceptible to weathering and dissolution.	[37]
Bentonite	Natural adsorbents with strong adsorption capacity; good coordination with the environment.	[38]
Shale	High removal ability of phosphorus and ammonia; good overall performance; derived from the lower limestone group of the Carboniferous system; high content of acid; higher specific surface area.	[39]
Apatite material	Lasting effect on the adoption of P; high economic cost of quality apatite.	[40]
Zeolite	High displacement ability to target ions; high porosity; high surface ratio; provide the environment for wetland system microorganisms; super to gravel in removing biodegradable-organics and nitrides; environmental damage caused by zeolite mining.	[41]
Sand	Widely distributed; low adsorption capacity and weak cation exchange capacity.	[42]
Calcite	Efficient removal of phosphorus and ammonium nitrogen; inefficient removal of nitrate.	[43]
Vermiculite	Good adsorption and ion exchange performance; selective adsorption for ammonia nitrogen; high ammonia nitrogen saturation adsorption capacity; low price.	[44]
Dolomite	Composed of calcium carbonate and magnesium carbonate; high phosphorus removal rate; low adsorption capacity and cation exchange capacity.	[45]
Shell	A sea-culture by-product or agriculture by-product; waste reuse; good adsorption capacity of P and N.	[46]
Bauxite	Excellent source of Al and Fe oxides; strong p-combining ability; high efficient adsorption capacity for toxic metals; high alkalinity treated water.	[47]
Rice straw	Agricultural waste; carbon source removal of nitrogen compounds; low cost; no secondary pollution; availability limited to harvest time.	[48]
Peat	Complex material composition; large amount; strong phosphorus adsorption capacity; lack of research on species.	[49]
Artificial products		
Activated carbon	Environmentally friendly; high cost and low adsorbing effect; complex production process.	[50]
Biochar	Wide source of raw materials; realize recycling; high porosity, high CES, and high surface area ratio; high efficiency of organic matter and nutrient removal; emission reduction N ₂ O; high energy consumption of pyrolysis.	[51]
Compost	Low investment; simple technology; recycling of resources; not environmental-friendly.	[52]
Ceramsite	Made of coal fly ash, sediment, etc., with drying and heating; high mechanical strength and developed microporous structures; re-utilization of waste; efficient in N and P removal; high preparation cost.	[48]

Lightweight aggregate	Hydraulic performance; light and handy; high cost; low intensity.	[53]
Calcium silicate hydrate	Porous; Large specific surface area; strong surface activity; lightweight; poor compatibility with organic polymers.	[54]
Polyethylene plastic	High porosity; no in-depth study.	[55]
<hr/> Industrial by-product		
Fly ash	Solid waste discharged from coal-fired boilers such as coal-fired power plants; plentiful and cheap; large specific surface area; high activation energy, abundant pore structure, and strong adsorption; not environmental-friendly.	[56]
Slag	Made from smelting industry waste; low cost; abundant raw material; recycling waste; high P adsorption capacity of arc furnace steel slag; different physicochemical properties of different slags.	[57]
Hollow brick crumbs	Active nitrogen and phosphorus adsorb abilities; construction waste; utilization of waste.	[50]
Wollastonite tailing	Efficient phosphorus removal; general adsorbability.	[58]
Alum sludge	A waste of waterworks; abundant; waste reuse; high transportation cost; high efficiency of phosphorus removal; low efficiency of nitrogen removal.	[59]
Moleanos limestone	Low cost and good usability; good performance in phosphorus removal.	[60]
Wood mulch	By-products of wood industry; waste reuse; abundant; Organic carbon source of heterotrophic denitrification; Strong ability to remove nitrogen compounds; no practical application.	[61]
Anthracite	High-density coal; long-lasting and efficient phosphorus removal effect; mining anthracite destroying the environment.	[62]
Calcite	Crushed stone and brick mixed; good for the growth of plants and microorganisms; ability to absorb phosphorus; facilitate microorganisms and plant growth; effective in P adsorption.	[63]
PHBV and PLA blend	A polymer biodegraded by microorganisms; improving nitrogen removal ability as a carbon source.	[64]
Red mud	A waste of aluminum industry; abundant; cheap; reuses waste; strong alkalinity; having ability to remove phosphorus.	[65]

For the selection of substrates used in the constructed wetland, cost and availability of raw materials should be given priority, especially in economically deprived areas [66]. Considering the cost and availability of raw materials, gravel, bentonite, shale, zeolite, sand, shell, rice straw, fly ash, hollow brick crumbs, and slag are suitable for mitigating N and P in agricultural runoff. To select the substrates with low cost and wide availability, the N and P removal capacities of 10 substrates were reviewed in detail.

Gravel is a commonly used filler substrate, with physical adsorption to achieve pollutant removal [67]. By artificial aeration, the constructed wetland with gravel can remove 58% of total nitrogen (TN) [67]. As a wetland substrate, bentonite can remove 66% of total phosphorus (TP) [68], showing good application prospects. In two constructed wetlands with shale as substrate and reed as plant, around 98%–100% of P was removed in 10-month cycling time [69]. In the constructed wetland with reeds as the plant, ammonia-nitrogen was removed nearly entirely; in the constructed wetland without reeds, the removal rate was only 40%–75% [69]. The zeolite, a natural ore, has a large adsorption rate for N and P due to its internal composition and spatial structure [70]. Specifically, zeolite-filters can enhance the removal ability of constructed wetland, with the removal percentages of organic matter, N and P being 95%, 80%, and 70%, respectively [71]. When the zeolite was used as the hybrid substrate, the removal rate of TN reached 80.3%–92.1% [72]. In constructed wetland with tall sheep grass as the plant, sand-soil was better than coarse sand soil in removing N [73]. In the wetland with sand as substrate, the removal capacity of P was 42%–91% [74]. Shells from both aquaculture and agriculture were proved to be effective removal of N and P [46]. For instance, palm kernel shells were effective in improving the N removal efficiency in constructed wetlands, compared with the counterpart with sand as the substrate [75]. Rice straw is also an effective material to remove nitrogenous compounds. In the floating constructed wetlands with rice straw as the substrate, the average removal rates of TN, ammonium nitrogen ($\text{NH}_4^+\text{-N}$), and nitrate-nitrogen ($\text{NO}_3^-\text{-N}$) were 78.2%, 81.2%, 62.1%, respectively [48]. Hollow brick crumbs and fly ash are also superior in the removal of TN and TP. The constructed wetland with hollow brick crumbs mixed with fly ash can cut down 89% of $\text{NH}_4^+\text{-N}$ and 81% of TP [28,76]. Slag was effective for the treatment of wastewater in constructed wetlands, and the removal rate of P was maintained at a high level [57,77,78]. Slag was 20% higher than gravel in respect of adsorption capacity of TP and the experiments witnessed a quick absorption saturation of TP by slag. A two-year experiment indicates similar N removal rates for slag and gravel [79].

The above review indicates that some substrates have been examined in the field, while others remain theoretical tests in the laboratory. The combination of substrates can enhance the removal performance of N and P. Considering the removal performance, availability, cost, toxicity, and recyclability [80], the top three optimum substrates for mitigating N and P from agricultural runoff are gravel, zeolite and, slag (including coal slag).

2.2. Plants Identification for Mitigating Nitrogen and Phosphorus from Agricultural Runoff

The plants commonly used in constructed wetlands can be divided into emergent plants, submerged plants, and free-floating plants [28]. More than 150 kinds of macrophytes have been used in constructed wetlands, but a systematic study in the field is still lacking [81]. Emergent plants have been identified as the most widely used plants in constructed wetlands [81] to treat agricultural runoff [82]. The plant species in wetlands play an important role in purifying agricultural runoff, which has been investigated in many countries, including China, Australia, Finland, Ireland, Italy, Korea, Norway, Singapore, Poland, Spain, Sweden, Ukraine, UK, and the USA (Table 2).

Table 2. Constructed wetland plants for the purification of N and P from agricultural runoff.

Vegetation	Country	References
<i>Phragmites</i> sp. (<i>australis</i>)	Australia, China, Poland, Spain, UK, Ukraine, France, Slovenia	[83–88]
<i>Phragmites</i> sp. (<i>japonica</i>)	Korea	[89]
<i>Phragmites</i> sp. (<i>karka</i>)	Singapore	[90]
<i>Scirpus</i> sp. (<i>californicus</i>)	USA	[91]
<i>Scirpus</i> sp. (<i>bulrush</i>)	USA	[91]
<i>Scirpus</i> sp. (<i>validus</i>)	Australia	[84]
<i>Scirpus</i> sp. (<i>sylvaticus</i>)	Finland	[92]
<i>Scirpus</i> sp. (<i>mucronatus</i>)	Singapore	[90]
<i>Typha</i> sp. (<i>latifolia</i>)	Finland, Norway, Poland, Sweden, UK, USA, France	[86–88,92–95]
<i>Typha</i> <i>domingensis</i>	USA	[91]
<i>Typha</i> sp. (<i>Cattail</i>)	USA	[91]
<i>Typha</i> sp. (<i>angustifolia</i>)	Singapore, Korea	[89,90]
<i>Iris</i> sp. (<i>pseudacorus</i>)	Finland, Norway, UK	[88,92,93]
<i>Phalaris</i> sp. (<i>arundinaces</i>)	Finland, Norway	[92,93]
<i>Alisma</i> sp. (<i>plantago-aquatica</i>)	Finland	[92]
<i>Filipendula</i> sp. (<i>ulmaria</i>)	Finland	[92]
<i>Juncus</i> sp. (<i>conglomeratus</i>)	Finland	[92]
<i>Carex</i> sp. (<i>riparia</i>)	UK	[88]
<i>Juncus</i> sp. (<i>effuses</i>)	Korea	[89]
<i>Miscanthus</i> sp. (<i>sinensis</i>)	Korea	[89]
<i>Eleocharis</i> sp. (<i>dulcis</i>)	Singapore	[90]
<i>Lepironia</i> sp. (<i>articulate</i>)	Singapore	[90]
<i>Sparganium</i> sp. (<i>erectum</i>)	Norway, UK	[88,93]
<i>Zizania</i> sp. (<i>caduciflora</i>)	China, Korea	[85,89]
<i>Glyceria maxima</i>	Poland	[87]
<i>Typha orientalis</i>	China, Korea	[85,89]
<i>Cyperus malaccensis</i>	China	[85]
<i>Juncus effusus</i>	Korea	[89]

Table 2 indicates that *Typha* spp., *Phragmites* spp. and *Scirpus* spp. are the most frequently used plants in the purification of agricultural runoff. Similarly, Vymazal et al. [96] found that *Phragmites* spp. (*Poaceae*), *Scirpus* spp. (*Cyperaceae*), *Typha* spp. (*Typhaceae*), *Juncus* spp. (*Juncaceae*), *Iris* spp. (*Iridaceae*), and *Eleocharis* spp. (*Spikerush*) are the most commonly used emergent plants in constructed wetlands. Compared with submerged plants and floating plants, emergent plants are more frequently used in constructed wetlands [81]. Hence, priority was given to the review of emergent plants for mitigating N and P in constructed wetlands.

The wetland planted with *Phragmites australis* can remove 60.74% TN, 93.07% NH₄-N, and 47.76% TP in an overall hydraulic residence time of four months [97]. Wetlands planted with *Phragmites* sp. and *Typha* sp. can remove TN by 79% and 77%, PO₄-P by 21% and 14%, within the overall hydraulic residence periods of 21 h and 27 h, respectively [98]. Similarly, *Typha angustifolia* was investigated in a pilot-scale constructed wetland, removing 80% NH₄⁺-N and 40% NO₃⁻-N [99]. In the wetland planted with *Typha orientalis*, the TN, NH₄-N, and TP removal efficiencies were 60.94%, 88.27%, and 63.21%, respectively, in an overall hydraulic residence time of four months [97]. Comparatively, the NO₃⁻-N,

$\text{NH}_4^+\text{-N}$, and P removal efficiencies of *Scirpus grossus* and *Typha angustifolia* were 52.1%, 59.4%, and 11.2%, and 51.6%, 56.5%, and 9.1%, respectively [100]. The wetland planted with *Scirpus mucronatus* witnessed the obvious reductions of TN (66.86%), $\text{NH}_4\text{-N}$ (89.35%), and TP (66.53%) in an overall hydraulic residence time of four months [97]. Similarly, remediation efficiency of *Juncus effuses* was examined, showing that *Juncus* plants fixed N and P around 28.5 g/m² and 1.69 g/m² [101]. Moreover, storm-water experienced a constant decline in TN (15.7%) and TP (47.7%) after 13 months of reaction in *Juncus effuses* planted wetlands [102]. Wetlands planted with *Iris pseudacorus* testified drops of TN, $\text{NH}_4\text{-N}$, and TP by 39.47%, 84.65%, and 26.28%, respectively, after an overall hydraulic residence time of four months [97]. Likewise, *Eleocharis dulcis* also showed the removal of TN and TP by 64.4% and 24.4%, respectively [103]. Apart from the most common emergent plants reviewed above, researchers also recommended *Eleocharis dulcis*, *Typha angustifolia*, and *Scirpus mucronatus* as the optimum plant species in surface flow wetlands [103].

In addition to single plant species, the combination of different plant species, substrate, climate, and management of constructed wetland all can affect the performance of N and P removals [104]. For example, the combination of *Typha* spp. with *Phragmites* spp. witnessed a gradual increase in the removal efficiency of nutrients such as N and P in constructed wetlands, which confirms the enhanced purification capacity by the combined plants [105]. The combination of plants with substrates can also improve the removal efficiency. *Iris pseudacorus* planted wetlands with fine gravel removed 49.4% TN and those with coarse gravel removed 31.4% TN, while unplanted wetlands were less (43.4% and 26.8%) [106].

Some researchers have compared the removal efficiencies of N and P between different species in the same conditions. For example, Sim et al. [103] ranked four common emergent plant species on the P removal (*Eleocharis dulcis* > *Scirpus mucronatus* > *Typha angustifolia* > *Phragmites karka*) and TN removal (*Eleocharis dulcis* > *Typha angustifolia* > *Scirpus mucronatus* > *Phragmites karka*). In addition, Wu et al. [97] compared the removal efficiencies of TN, $\text{NH}_4^+\text{-N}$, and TP by *Typha orientalis*, *Iris pseudacorus*, *Phragmites australis*, and *Scirpus validus*. The four plants demonstrated the order of TP removal abilities (*Typha orientalis* > *Scirpus validus* > *Phragmites australis* > *Iris pseudacorus*).

By reviewing the above comparative studies, these commonly used emergent plants can be ranked on the mitigation of N and P in the following order: *Eleocharis dulcis* > *Typha orientalis* > *Scirpus validus* > *Phragmites australis* > *Iris pseudacorus*.

Compared with emergent plants, submerged plants and floating plants are less prominent in the constructed wetland. Among the submerged plants, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Myriophyllum verticillatum*, *Vallisneria natans*, and *Potamogeton crispus* are commonly used in constructed wetland [28]. *Ceratophyllum demersum* played an important role in the removal of TN and TP, with 27.5% and 86.19%, respectively [107]. *Hydrilla verticillata* dominated constructed wetland experienced a fall in TP concentration from 126 µg/L to 106 µg/L [108]. *Myriophyllum verticillatum*, a plant in surface flow constructed wetlands, displayed the outstanding removal ability of TP by roughly 70.1% [77]. *Potamogeton Crispus* with *Hydrilla verticillata* in the wetland can remove organic N and organic P by 81.28% and 83.54%, respectively [109]. Despite no study stating clearly the purification capacity of *Vallisneria natans*, it was verified that P absorption by *Vallisneria natans* can be promoted by organic acids [110]. Some studies have compared the N and P removal performance of different submerged plants in the same conditions. The highest removal efficiency of N and P occurred in *Hydrilla verticillata*, followed by *Ceratophyllum demersum*, *Vallisneria natans*, *Myriophyllum spicatum*, and *Potamogeton maackianus*, in laboratory simulated hydrostatic conditions [111]. Therefore, the top optimum three submerged plants in the constructed wetland are *Hydrilla verticillata*, *Ceratophyllum demersum*, and *Vallisneria natans*.

Different from emergent plant and submerged plants, floating plants are divided into free-floating species and floating-leaved species. The commonly used free-floating plants

in constructed wetlands include *Lemna minor*, *Eichhornia crassipes*, *Salvinia natans*, and *Hydrocharis dubia*. Meanwhile, floating-leaved species in constructed wetlands are mainly *Nymphoides peltata*, *Trapa bispinosa*, *Nymphaea tetragona*, and *Marsilea quadrifolia* [28].

Applying *Lemna minor* in constructed wetlands, the removal rates of TN and TP exceeded 50% and 90% [112]. Moreover, *Najas minor*'s removal efficiencies on TN and TP were 55% and 93% [113]. *Eichhornia crassipes* and *Salvinia natans* used for the wastewater treatment can remove 53.0% TN and 56.6% TP [114]. A 100-day reaction indicated that *Eichhornia crassipes* removed 57% TN and 52% TP, while *Hydrocharis dubia* eliminated less (46% TN and 45% TP) [115]. Moreover, *Nymphaea tetragona* [116], *Trapa bispinosa*, and *Marsilea quadrifolia* were used as constructed wetland plants to remove N and P [117]. Some scholars have compared the removal performances of floating plants. For the free-floating plants, the highest N and P removal performances occurred in *Eichhornia*, followed by *Lemna*, *Salvinia* [118]. *Eichhornia* is also far superior to *Hydrocharis dubia* in the view of removing N and P [119]. For the floating-leaved plants, Greenway [120] ranked the plants on the N and P removal (*Lemna minor* > *Nymphaea tetragona* > *Nymphoides peltata*). Moreover, Marion and Paillisson [121] sorted three species on the N and P removal performance in the order: *Nymphaea tetragona* > *Trapa bispinosa* > *Nymphoides peltata*.

Based on the above comparative studies, it can be drawn that *Eichhornia crassipes* and *Lemna minor* are the optimum free-floating plants, and *Nymphaea tetragona* and *Trapa bispinosa* are the optimum floating-leaved plants for mitigating N and P from agricultural runoff.

Among the aquatic plants mentioned above, emergent plants are most widely used in constructed wetlands [81]. *Phragmites* spp. is the most frequent species in Asia and Europe [82]. *Scirpus* spp., including *lacustris*, *validus*, and *californicus*, are commonly used in North America, New Zealand, and Australia [28]. *Juncus* and *Eleocharis* spp. are utilized commonly in Europe, North America, and Asia [82]. *Iris* spp. is mainly used in tropical and subtropical regions [122].

Overall, to mitigate N and P in the agricultural runoff by constructed wetland, in terms of emergent plants, *Eleocharis dulcis*, *Typha orientalis*, and *Scirpus validus* are the top three optimum species; as regards to submerged plants, *Hydrilla verticillata*, *Ceratophyllum demersum*, and *Vallisneria natans* are advocated; for the free-floating plants, *Eichhornia crassipes*, and *Lemna minor* are appropriate; and regarding the floating-leaved plants, *Nymphaea tetragona* and *Trapa bispinosa* are the promoted species.

3. Site Selection of Constructed Wetland to Mitigate Nitrogen and Phosphorus in Agricultural Runoff

During the process of selecting sites for constructed wetlands, multiple factors should be considered comprehensively, completely, and correctly [123]. From the perspective of practical operation, a series of maps containing the topographic map, geological map, aerial image map, soil survey map, and hydrological map should be compiled for the comprehensive selection of wetland sites [124]. Many studies have demonstrated the importance of climate, rainfall, geography, surface water, soil, biology, and socio-economic factors [125–127].

Natural factors play an important role in the site selection of constructed wetland, especially the elemental items—(i) closing to pollution sources as possible as it can, (ii) minimizing earthwork by maximizing natural slope, and (iii) estimating watershed area to control wastewater retention time. Apart from natural factors, the protection of human and natural resources is an assignable part, requiring keeping away from nature reserves, historical and cultural reserves, archaeological control areas, planned and construction areas, and others. The Geographic Information System (GIS) is one of the important technologies for geographic exploration, which has been widely used in land administration, traffic planning, environmental analysis, and planning [128]. At present, it has been increasingly used in the site selection of public service facilities such as hospitals and schools. Furthermore, GIS combined with remote sensing (RS) has been used to map the

isolated wetlands in a karst landscape [129]. Moreover, GIS has been used for site evaluation of constructed wetlands and restored wetlands in the agricultural catchment [130]. Combining the existing research and the characteristics of constructed wetlands, this paper reviewed and sorted out the technical method using GIS for the site selection of constructed wetlands to mitigate N and P from agricultural runoff (Figure 2).

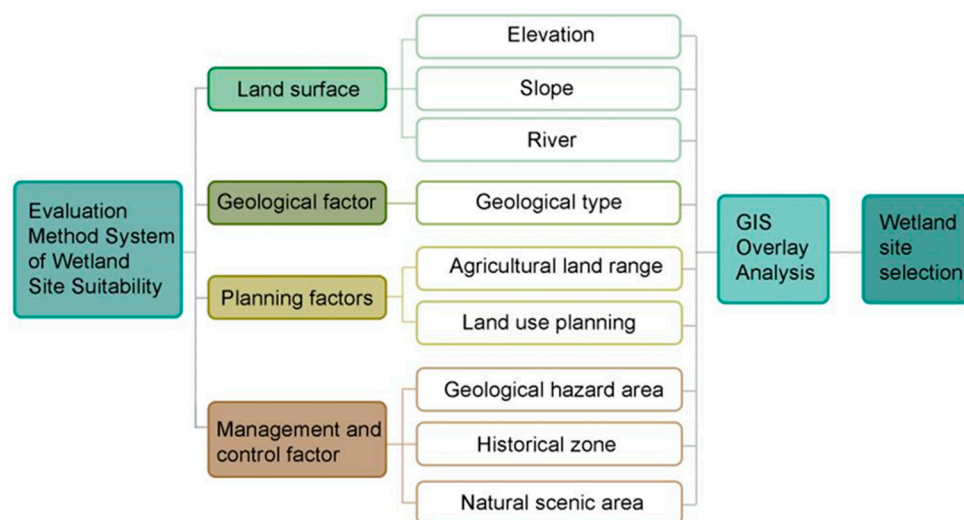


Figure 2. Technical route of constructed wetland site selection using Geographical Information System (GIS).

4. Structural Design of Constructed Wetland to Mitigate Nitrogen and Phosphorus in Agricultural Runoff

The design parameters of constructed wetlands consist of wetland substrate, plants, water depth, aspect ratios, and others [131]. These substantial factors are possibly expressed in various forms, for instance, water depth, hydraulic load and retention time, and feeding mode of the inlet [132].

Fillers play a key role in the construction of wetlands. Various substrates have been elaborated in Section 2.1. When the substrate species were selected, attention will be paid to the particle size of the filler, which has a significant effect on the removal efficiency [133]. The comparison of four types of wetland beds with different particle sizes in the same environmental conditions indicates that the smaller the particle size, the better the P removal efficiency [134]. Specifically, the maximum P adsorption capacities of three filter media with the sizes of 4–10 mm, 2–4 mm, 0.1–2 mm were 7.7 mg/kg, 11.6 mg/kg, and 22.5 mg/kg, respectively, indicating that the adsorption capacity increased with the decrease of media sizes [135].

In addition to particle size, the substrates with additives, for example, iron oxides, iron hydroxides, Lu oxides, Lu hydroxides, and calcium, can increase the P removal efficiency of constructed wetlands [135–137]. The comparison of adding Ca, Mg, Al, and Fe to a filter medium indicated that Ca had the maximum enhancement of nutrient removal [135]. Similarly, a study on the oyster shell as the additive indicated that adding 2% of oyster shell could increase the adsorption capacity of P from 23 mg/kg to 36 mg/kg, and adsorption capacity rose until the oyster shell concentration came over 60% [135].

Plants are an important part of constructed wetlands, and different species have been reviewed in Section 2.2. Notably, priority should be given to local plants to prevent the invasion of alien species [138].

Water depth is an important factor affecting the water load and oxygen permeability [139]. A comparison in the denitrification effects of subsurface flow horizontal wetlands between depths of 0.27 m and 0.50 m indicated that the wetlands at depth of 0.27 m worked better than those of 0.50 m [140].

In addition, the ratio of length to width of wetland bed can affect the removal of N and P [141]. The ratio can affect the linear velocity of water flow, causing head loss [142]. Therefore, the ratio should not be too large. On the other hand, some scholars suggest that the ratio of length to width had a limited effect on N and P removal [140]. However, the existing research related to the ratio of length to width has not yet reached an agreement. Therefore, the impact of the length-width ratio of constructed wetland on its performance is far from clearly understood and further study is still necessary.

5. Concluding Remarks and Future Outlooks

Constructed wetland plays an irreplaceable role in the mitigation of N and P, especially in the economically deprived areas. Despite many studies on the related topics of constructed wetland, most of the studies only focused on the interaction of a certain substance with the performance of constructed wetland under artificially designed experimental conditions, suggesting the limited practical application of the findings. This review summarized the principles, influencing factors, site selection, and structural design of constructed wetlands in the treatment of N and P from agricultural runoff, which has a strong application.

This review suggests that the top three recommended substrates for mitigating N and P from agricultural runoff are gravel, zeolite, and slag (including coal slag). Emergent plants are the most widely used plants in constructed wetlands, and *Eleocharis dulcis*, *Typha orientalis*, and *Scirpus validus* have better performance in mitigating N and P from agricultural runoff. Similarly, *Hydrilla verticillata*, *Ceratophyllum demersum*, and *Vallisneria spiralis* are the recommended submerged plants; *Eichhornia crassipes* and *Lemna minor* are the advocated free-floating plants; and *Nymphaea tetragona* and *Trapa bispinosa* are the promoted floating-leaved plants. Moreover, the selection of wetland site was summarized, and the technical route of site selection using GIS was put forward. However, the optimal structure design of constructed wetland has not been obtained, due to the lack of systematic research on the wetland structure design.

Despite the progress of the studies on the constructed wetlands, research gaps still exist in our understanding of constructed wetlands for mitigating N and P in agricultural runoff. In addition, climate change will further influence the N and P diffusion pollution from agricultural runoff [143]. To fill these research gaps, the following issues deserve more attention:

- (1) It is important to conduct more comparative studies on substrates' performance under the same external conditions in different climatic regions.
- (2) The current plant selection focused on the effects of plant species on the mitigation of N and P, ignoring the complexity of plants' contribution to the performance constructed wetland. It is essential to study the competitive effects between different plant species and the interactions between plants and substrates.
- (3) Because the relationship between constructed wetland structure and performance is still debated, more studies on the effect of wetland structure on its performance of removing N and P are largely needed.

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References

1. Carmichael, W.W.; Boyer, G.L. Health impacts from cyanobacteria harmful algae blooms: Implications for the north American Great Lakes. *Harmful Algae* **2016**, *54*, 194–212, doi:10.1016/j.hal.2016.02.002.
2. Zhang, M.; Xie, P.; Xu, J.; Liu, B.; Yang, H. Spatiotemporal variations of internal P-loading and the related mechanisms in the large shallow Lake Chaohu. *Sci. China Ser. D Earth Sci.* **2006**, *49*, 72–81, doi:10.1007/s11430-006-8107-7.
3. Yang, H.; Yi, C.; Xie, P.; Xing, Y.; Ni, L. Sedimentation rates, nitrogen and phosphorus retentions in the largest urban Lake Donghu, China. *J. Radioanal. Nucl. Chem.* **2005**, *267*, 205–208, doi:10.1007/s10967-006-0028-6.
4. Ma, X.; Wang, L.; Yang, H.; Li, N.; Gong, C. Spatiotemporal analysis of water quality using multivariate statistical techniques and the water quality identification index for the Qinhuai River basin, east China. *Water* **2020**, *12*, 2764, doi:10.3390/w12102764.
5. Shakyia, R.; Adhikari, S.; Mahadevan, R.; Shanmugam, S.R.; Nam, H.; Hassan, E.B.; Dempster, T.A. Influence of biochemical composition during hydrothermal liquefaction of algae on product yields and fuel properties. *Bioresour. Technol.* **2017**, *243*, 1112–1120, doi:10.1016/j.biortech.2017.07.046.
6. Shan, K.; Wang, X.; Yang, H.; Zhou, B.; Song, L.; Shang, M. Use statistical machine learning to detect nutrient thresholds in Microcystis blooms and microcystin management. *Harmful Algae* **2020**, *94*, 101807, doi:10.1016/j.hal.2020.101807.
7. Díaz, P.A.; Álvarez, G.; Varela, D.; Pérez-Santos, I.; Díaz, M.; Molinet, C.; Seguel, M.; Aguilera-Belmonte, A.; Guzmán, L.; Uribe, E.; et al. Impacts of harmful algal blooms on the aquaculture industry: Chile as a case study. *Perspect. Phycol.* **2019**, *6*, 39–50, doi:10.1127/pip/2019/0081.
8. Mohajerani, A.; Bakaric, J.; Jeffrey-Bailey, T. The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *J. Environ. Manag.* **2017**, *197*, 522–538, doi:10.1016/j.jenvman.2017.03.095.
9. Yang, H.; Xie, P.; Ni, L.; Flower, R.J. Pollution in the Yangtze. *Science* **2012**, *337*, 410, doi:10.1126/science.337.6093.410-a.
10. Paerl, H.W.; Gardner, W.S.; Havens, K.E.; Joyner, A.R.; McCarthy, M.J.; Newell, S.E.; Qin, B.; Scott, J.T. Mitigating cyanobacterial harmful algal blooms in aquatic ecosystems impacted by climate change and anthropogenic nutrients. *Harmful Algae* **2016**, *54*, 213–222, doi:10.1016/j.hal.2015.09.009.
11. Yang, H.; Flower, R.J.; Thompson, J.R. Sustaining China's water resources. *Science* **2013**, *339*, 141.
12. Yang, H.; Wright, J.A.; Gundry, S.W. Boost water safety in rural China. *Nat. Cell Biol.* **2012**, *484*, 318, doi:10.1038/484318b.
13. Paerl, H.W. Controlling eutrophication along the freshwater–marine continuum: Dual nutrient (N and P) reductions are essential. *Chesap. Sci.* **2009**, *32*, 593–601, doi:10.1007/s12237-009-9158-8.
14. Hamilton, D.P.; Salmaso, N.; Paerl, H.W. Mitigating harmful cyanobacterial blooms: Strategies for control of nitrogen and phosphorus loads. *Aquat. Ecol.* **2016**, *50*, 351–366, doi:10.1007/s10452-016-9594-z.
15. Kvakić, M.; Pellerin, S.; Ciais, P.; Achat, D.L.; Augusto, L.; Denoroy, P.; Gerber, J.S.; Goll, D.; Mollier, A.; Mueller, N.D.; et al. Quantifying the limitation to world cereal production due to soil phosphorus status. *Glob. Biogeochem. Cycles* **2018**, *32*, 143–157, doi:10.1002/2017gb005754.
16. Dawson, C.; Hilton, J. Fertiliser availability in a resource-limited world: Production and recycling of nitrogen and phosphorus. *Food Policy* **2011**, *36*, S14–S22, doi:10.1016/j.foodpol.2010.11.012.
17. Cole, J.C.; Smith, M.W.; Penn, C.J.; Cheary, B.S.; Conaghan, K.J. Nitrogen, phosphorus, calcium, and magnesium applied individually or as a slow release or controlled release fertilizer increase growth and yield and affect macronutrient and micronutrient concentration and content of field-grown tomato plants. *Sci. Hortic.* **2016**, *211*, 420–430, doi:10.1016/j.scienta.2016.09.028.
18. Yang, H.; Shen, X.; Lai, L.; Huang, X.; Zhou, Y. Spatio-temporal variations of health costs caused by chemical fertilizer utilization in China from 1990 to 2012. *Sustainability* **2017**, *9*, 1505, doi:10.3390/su9091505.
19. Bennetzen, E.H.; Smith, P.; Porter, J.R. Agricultural production and greenhouse gas emissions from world regions—The major trends over 40 years. *Glob. Environ. Chang.* **2016**, *37*, 43–55, doi:10.1016/j.gloenvcha.2015.12.004.
20. Yang, H. China's soil plan needs strong support. *Nature* **2016**, *536*, 375.
21. García, J.; Ortiz, A.; Álvarez, E.; Belohlav, V.; García-Galán, M.J.; Díez-Montero, R.; Álvarez, J.A.; Uggetti, E. Nutrient removal from agricultural run-off in demonstrative full scale tubular photobioreactors for microalgae growth. *Ecol. Eng.* **2018**, *120*, 513–521, doi:10.1016/j.ecoleng.2018.07.002.
22. Yang, H. China must continue the momentum of green law. *Nat. Cell Biol.* **2014**, *509*, 535, doi:10.1038/509535a.
23. Yang, H.; Huang, X.; Thompson, J.R.; Flower, R.J. Enforcement key to China's environment. *Science* **2015**, *347*, 834–835.
24. Gregoire, C.; Elsaesser, D.; Huguenot, D.; Lange, J.; Lebeau, T.; Merli, A.; Mose, R.; Passeport, E.; Payraudeau, S.; Schuetz, T.; et al. Mitigation of agricultural nonpoint-source pesticide pollution in artificial wetland ecosystems—A review. In *Climate Change, Intercropping, Pest Control and Beneficial Microorganisms*; Springer International Publishing: Dordrecht, The Netherlands, 2009; pp. 293–338.
25. Kumwimba, M.N.; Meng, F.; Iseyemi, O.; Moore, M.T.; Zhu, B.; Tao, W.; Liang, T.J.; Ilunga, L. Removal of non-point source pollutants from domestic sewage and agricultural runoff by vegetated drainage ditches (VDDs): Design, mechanism, management strategies, and future directions. *Sci. Total Environ.* **2018**, *639*, 742–759, doi:10.1016/j.scitotenv.2018.05.184.

26. Balana, B.B.; Vinten, A.; Slee, B. A review on cost-effectiveness analysis of agri-environmental measures related to the EU WFD: Key issues, methods, and applications. *Ecol. Econ.* **2011**, *70*, 1021–1031, doi:10.1016/j.ecolecon.2010.12.020.
27. Vymazal, J. Constructed wetlands for treatment of industrial wastewaters: A review. *Ecol. Eng.* **2014**, *73*, 724–751, doi:10.1016/j.ecoleng.2014.09.034.
28. Nan, X.; Lavrnić, S.; Toscano, A. Potential of constructed wetland treatment systems for agricultural wastewater reuse under the EU framework. *J. Environ. Manag.* **2020**, *275*, 111219, doi:10.1016/j.jenvman.2020.111219.
29. Xiaoyan, T.; Suyu, W.; Yang, Y.; Ran, T.; Yunv, D.; Dan, A.; Li, L. Removal of six phthalic acid esters (PAEs) from domestic sewage by constructed wetlands. *Chem. Eng. J.* **2015**, *275*, 198–205, doi:10.1016/j.cej.2015.04.029.
30. Wu, H.; Gao, X.; Wu, M.; Zhu, Y.; Xiong, R.; Ye, S. The efficiency and risk to groundwater of constructed wetland system for domestic sewage treatment—A case study in Xiantao, China. *J. Clean. Prod.* **2020**, *277*, 123384, doi: 10.1016/j.jclepro.2020.123384.
31. Samsó, R.; García, J.; Molle, P.; Forquet, N. Modelling bioclogging in variably saturated porous media and the interactions between surface/subsurface flows: Application to constructed wetlands. *J. Environ. Manag.* **2016**, *165*, 271–279, doi:10.1016/j.jenvman.2015.09.045.
32. Vymazal, J.; Březinová, T. The use of constructed wetlands for removal of pesticides from agricultural runoff and drainage: A review. *Environ. Int.* **2015**, *75*, 11–20, doi:10.1016/j.envint.2014.10.026.
33. Bouldin, J.; Farris, J.; Moore, M.; Smith, S.; Cooper, C. Hydroponic uptake of atrazine and lambda-cyhalothrin in *Juncus effusus* and *Ludwigia peploides*. *Chemosphere* **2006**, *65*, 1049–1057, doi:10.1016/j.chemosphere.2006.03.031.
34. Vymazal, J. Removal of nutrients in various types of constructed wetlands. *Sci. Total Environ.* **2007**, *380*, 48–65, doi:10.1016/j.scitotenv.2006.09.014.
35. Korkusuz, E.A.; Beklioğlu, M.; Demirel, G.N. Comparison of the treatment performances of blast furnace slag-based and gravel-based vertical flow wetlands operated identically for domestic wastewater treatment in Turkey. *Ecol. Eng.* **2005**, *24*, 185–198, doi:10.1016/j.ecoleng.2004.10.002.
36. Boyer, A.; Ning, P.; Killey, D.; Klukas, M.; Rowan, D.; Simpson, A.J.; Passeport, E. Strontium adsorption and desorption in wetlands: Role of organic matter functional groups and environmental implications. *Water Res.* **2018**, *133*, 27–36, doi:10.1016/j.watres.2018.01.026.
37. Yang, Y.; Zhao, Y.; Liu, R.; Morgan, D. Global development of various emerged substrates utilized in constructed wetlands. *Bioresour. Technol.* **2018**, *261*, 441–452, doi:10.1016/j.biortech.2018.03.085.
38. Magda, K.; Hanna, O.P.; Fabio, M.; Magdalena, G. Possibilities of phoslock® application to remove phosphorus compounds from wastewater treated in hybrid wetlands. *Ecol. Eng.* **2018**, *122*, 84–90.
39. Drizo, A.; Frost, C.A.; Smith, K.A.; Grace, J. Phosphate and ammonium removal by constructed wetlands with horizontal subsurface flow, using shale as a substrate. *Water Sci. Technol.* **1997**, *35*, 95–102.
40. Harouiya, N.; Rue, S.M.; Prost-Boucle, S.; Liénar, A.; Esser, D.; Molle, P. Phosphorus removal by apatite in horizontal flow constructed wetlands for small communities: Pilot and full-scale evidence. *Water Sci. Technol. J. Int. Assoc. Water Pollut. Res.* **2011**, *63*, 1629.
41. Babel, S.; Kurniawan, T.A. Low-cost adsorbents for heavy metals uptake from contaminated water: A review. *J. Hazard. Mater.* **2003**, *97*, 219–243.
42. Zhao, Z.; Chang, J.; Han, W.; Wang, M.; Ma, D.; Du, Y.; Qu, Z.; Chang, S.X.; Ge, Y. Effects of plant diversity and sand particle size on methane emission and nitrogen removal in microcosms of constructed wetlands. *Ecol. Eng.* **2016**, *95*, 390–398, doi:10.1016/j.ecoleng.2016.06.047.
43. Seo, D.C.; Hwang, S.H.; Kim, H.J.; Cho, J.S.; Lee, H.J.; Delaune, R.D.; Jugsujinda, A.; Lee, S.T.; Seo, J.Y.; Heo, J.S. Evaluation of 2- and 3-stage combinations of vertical and horizontal flow constructed wetlands for treating greenhouse wastewater. *Ecol. Eng.* **2008**, *32*, 121–132, doi:10.1016/j.ecoleng.2007.10.007.
44. Wang, H.X.; Xu, J.L.; Sheng, L.X.; Liu, X.J. A review of research on substrate materials for constructed wetlands. *Mater. Sci. Forum* **2018**, *913*, 917–929, doi:10.4028/www.scientific.net/msf.913.917.
45. Sharma, P.K.; Minakshi, D.; Rani, A.; Malaviya, P. Treatment efficiency of vertical flow constructed wetland systems operated under different recirculation rates. *Ecol. Eng.* **2018**, *120*, 474–480, doi:10.1016/j.ecoleng.2018.07.004.
46. Park, W.; Polprasert, C. Roles of oyster shells in an integrated constructed wetland system designed for P removal. *Ecol. Eng.* **2008**, *34*, 50–56, doi:10.1016/j.ecoleng.2008.05.014.
47. Cherukumilli, K.; Delaire, C.; Amrose, S.; Gadgil, A.J. Factors governing the performance of bauxite for fluoride remediation of groundwater. *Environ. Sci. Technol.* **2017**, *51*, 2321–2328, doi:10.1021/acs.est.6b04601.
48. Cao, W.; Wang, Y.; Sun, L.; Jiang, J.; Zhang, Y. Removal of nitrogenous compounds from polluted river water by floating constructed wetlands using rice straw and ceramsite as substrates under low temperature conditions. *Ecol. Eng.* **2016**, *88*, 77–81, doi:10.1016/j.ecoleng.2015.12.019.
49. Gupta, V.K.; Carrott, P.J.M.; Carrott, M.M.L.R.; Suhas. Low-cost adsorbents: Growing approach to wastewater treatment—A review. *Crit. Rev. Environ. Sci. Technol.* **2009**, *39*, 783–842, doi:10.1080/10643380801977610.
50. Ren, Y.; Zhang, B.; Zhen, L.; Jin, W. Optimization of four kinds of constructed wetlands substrate combination treating domestic sewage. *Wuhan Univ. J. Nat. Sci.* **2007**, *12*, 1136–1142.
51. Kizito, S.; Lv, T.; Wu, S.; Ajmal, Z.; Luo, H.; Dong, R. Treatment of anaerobic digested effluent in biochar-packed vertical flow constructed wetland columns: Role of media and tidal operation. *Sci. Total Environ.* **2017**, *592*, 197–205, doi:10.1016/j.scitotenv.2017.03.125.

52. Gandy, C.J.; Davis, J.E.; Orme, P.H.; Potter, H.A.; Jarvis, A.P. Metal removal mechanisms in a short hydraulic residence time subsurface flow compost wetland for mine drainage treatment. *Ecol. Eng.* **2016**, *97*, 179–185, doi:10.1016/j.ecoleng.2016.09.011.
53. Meng, P.; Pei, H.; Hu, W.; Shao, Y.; Li, Z. Performance evaluation of light-weight aggregates-based horizontal flow constructed wetlands for domestic wastewater treatment. *CLEAN Soil Air Water* **2014**, *43*, 217–222, doi:10.1002/clen.201300058.
54. Li, C.; Dong, Y.; Lei, Y.; Wu, D.; Xu, P. Removal of low concentration nutrients in hydroponic wetlands integrated with zeolite and calcium silicate hydrate functional substrates. *Ecol. Eng.* **2015**, *82*, 442–450, doi:10.1016/j.ecoleng.2015.05.003.
55. Tatoulis, T.; Akrotos, C.S.; Tekerlekopoulou, A.G.; Vayenas, D.V.; Stefanakis, A.I. A novel horizontal subsurface flow constructed wetland: Reducing area requirements and clogging risk. *Chemosphere* **2017**, *186*, 257–268, doi:10.1016/j.chemosphere.2017.07.151.
56. Cheng, G.; Li, Q.; Su, Z.; Sheng, S.; Fu, J. Preparation, optimization, and application of sustainable ceramsite substrate from coal fly ash/waterworks sludge/oyster shell for phosphorus immobilization in constructed wetlands. *J. Clean. Prod.* **2018**, *175*, 572–581, doi:10.1016/j.jclepro.2017.12.102.
57. Blanco, I.; Molle, P.; De Miera, L.E.S.; Ansola, G. Basic oxygen furnace steel slag aggregates for phosphorus treatment. Evaluation of its potential use as a substrate in constructed wetlands. *Water Res.* **2016**, *89*, 355–365, doi:10.1016/j.watres.2015.11.064.
58. Brooks, A.S.; Rozenwald, M.N.; Geohring, L.D.; Lion, L.W.; Steenhuis, T.S. Phosphorus removal by wollastonite: A constructed wetland substrate. *Ecol. Eng.* **2000**, *15*, 121–132, doi:10.1016/S0925-8574(99)00056-7.
59. Hu, Y.; Zhao, Y.; Zhao, X.; Kumar, J.L.G. High rate nitrogen removal in an alum sludge-based intermittent aeration constructed wetland. *Environ. Sci. Technol.* **2012**, *46*, 4583–4590, doi:10.1021/es204105h.
60. Mateus, D.M.; Vaz, M.M.; Capela, I.; Pinho, H.J. Sugarcane as constructed wetland vegetation: Preliminary studies. *Ecol. Eng.* **2014**, *62*, 175–178, doi:10.1016/j.ecoleng.2013.10.031.
61. Saeed, T.; Sun, G. A comparative study on the removal of nutrients and organic matter in wetland reactors employing organic media. *Chem. Eng. J.* **2011**, *171*, 439–447, doi:10.1016/j.cej.2011.03.101.
62. Zhang, X.; Guo, L.; Wang, Y.; Ruan, C. Removal of oxygen demand and nitrogen using different particle-sizes of anthracite coated with nine kinds of LDHs for wastewater treatment. *Sci. Rep.* **2015**, *5*, 15146, doi:10.1038/srep15146.
63. Shi, X.; Fan, J.; Zhang, J.; Shen, Y. Enhanced phosphorus removal in intermittently aerated constructed wetlands filled with various construction wastes. *Environ. Sci. Pollut. Res.* **2017**, *24*, 22524–22534, doi:10.1007/s11356-017-9870-z.
64. Yang, Z.; Yang, L.; Wei, C.; Wu, W.; Zhao, X.; Lu, T. Enhanced nitrogen removal using solid carbon source in constructed wetland with limited aeration. *Bioresour. Technol.* **2018**, *248*, 98–103, doi:10.1016/j.biortech.2017.07.188.
65. Yanzhong, L.; Changjun, L.; Zhaokun, L.; Xianjia, P.; Chunlei, Z.; Zhaoyang, C.; Zhongguo, Z.; Jinghua, F.; Zhiping, J. Phosphate removal from aqueous solutions using raw and activated red mud and fly ash. *J. Hazard. Mater.* **2006**, *137*, 374–383.
66. Dordio, A.V.; Carvalho, A.J.P. Organic xenobiotics removal in constructed wetlands, with emphasis on the importance of the support matrix. *J. Hazard. Mater.* **2013**, *272*–292, doi:10.1016/j.jhazmat.2013.03.008.
67. Lin, J.; Tu, Y.; Chiang, P.; Chen, S.; Kao, C. Using aerated gravel-packed contact bed and constructed wetland system for polluted river water purification: A case study in Taiwan. *J. Hydrol.* **2015**, *525*, 400–408, doi:10.1016/j.jhydrol.2015.03.049.
68. Younger, P.L.; Henderson, R. Synergistic wetland treatment of sewage and mine water: Pollutant removal performance of the first full-scale system. *Water Res.* **2014**, *55*, 74–82, doi:10.1016/j.watres.2014.02.024.
69. Jones, J.; Chang, N.-B.; Wanielista, M.P. Reliability analysis of nutrient removal from stormwater runoff with green sorption media under varying influent conditions. *Sci. Total Environ.* **2015**, *502*, 434–447, doi:10.1016/j.scitotenv.2014.09.016.
70. Sethia, G.; Somani, R.S.; Bajaj, H.C. Adsorption of carbon monoxide, methane and nitrogen on alkaline earth metal ion exchanged zeolite-X: Structure, cation position and adsorption relationship. *RSC Adv.* **2015**, *5*, 12773–12781, doi:10.1039/c4ra11511b.
71. Stefanakis, A.I.; Akrotos, C.S.; Gikas, G.D.; Tsihrintzis, V.A. Effluent quality improvement of two pilot-scale, horizontal subsurface flow constructed wetlands using natural zeolite (clinoptilolite). *Microporous Mesoporous Mater.* **2009**, *124*, 131–143, doi:10.1016/j.micromeso.2009.05.005.
72. He, H.; Duan, Z.; Wang, Z.; Yue, B. The removal efficiency of constructed wetlands filled with the zeolite-slag hybrid substrate for the rural landfill leachate treatment. *Environ. Sci. Pollut. Res.* **2017**, *24*, 17547–17555, doi:10.1007/s11356-017-9402-x.
73. Han W.; Shi, M.; Chang, J.; Ren, Y.; Xu, R.; Zhang, C.; Ge, Y. Plant species diversity reduces N₂O but not CH₄ emissions from constructed wetlands under high nitrogen levels. *Environ. Sci. Pollut. Res.* **2017**, *24*(6), 5938–5948, doi: 10.1007/s11356-016-8288-3.
74. De Rozari, P.; Greenway, M.; El Hanandeh, A. Phosphorus removal from secondary sewage and septage using sand media amended with biochar in constructed wetland mesocosms. *Sci. Total Environ.* **2016**, *123*–133, doi:10.1016/j.scitotenv.2016.06.096.
75. Jong, V.S.W.; Tang, F.E. The use of palm kernel shell (PKS) as substrate material in vertical-flow engineered wetlands for septage treatment in Malaysia. *Water Sci. Technol.* **2015**, *72*, 84–91, doi:10.2166/wst.2015.186.
76. Kumar, S.; Dutta, V. Efficiency of Constructed Wetland Microcosms (CWMs) for the treatment of domestic wastewater using aquatic macrophytes. In *Environmental Biotechnology: For Sustainable Future*; Springer International Publishing: Singapore, 2019; pp. 287–307.
77. Luo, P.; Liu, F.; Liu, X.; Wu, X.; Yao, R.; Chen, L.; XinLiang, L.; Xiao, R.; Wu, J. Phosphorus removal from lagoon-pretreated swine wastewater by pilot-scale surface flow constructed wetlands planted with *Myriophyllum aquaticum*. *Sci. Total Environ.* **2017**, *576*, 490–497, doi:10.1016/j.scitotenv.2016.10.094.

78. Park, J.-H.; Kim, S.-H.; Delaune, R.D.; Kang, B.-H.; Kang, S.-W.; Cho, J.-S.; Ok, Y.S.; Seo, D.-C. Enhancement of phosphorus removal with near-neutral pH utilizing steel and ferronickel slags for application of constructed wetlands. *Ecol. Eng.* **2016**, *95*, 612–621, doi:10.1016/j.ecoleng.2016.06.052.
79. Ge, Y.; Wang, X.; Zheng, Y.; Dzakpasu, M.; Zhao, Y.; Xiong, J. Functions of slags and gravels as substrates in large-scale demonstration constructed wetland systems for polluted river water treatment. *Environ. Sci. Pollut. Res.* **2015**, *22*, 12982–12991, doi:10.1007/s11356-015-4573-9.
80. Ballantine, D.J.; Tanner, C.C. Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff: A review. *N. Z. J. Agric. Res.* **2010**, *53*, 71–95, doi:10.1080/00288231003685843.
81. Vymazal, J. The use of hybrid constructed wetlands for wastewater treatment with special attention to nitrogen removal: A review of a recent development. *Water Res.* **2013**, *47*, 4795–4811, doi:10.1016/j.watres.2013.05.029.
82. Vymazal, J. Plants used in constructed wetlands with horizontal subsurface flow: A review. *Hydrobiologia* **2011**, *674*, 133–156, doi:10.1007/s10750-011-0738-9.
83. Moreno-Mateos, D.; Pedrocchi, C.; Comín, F.A.; García-Antón, M.; Cabezas, A. Creating wetlands for the improvement of water quality and landscape restoration in semi-arid zones degraded by intensive agricultural use. *Ecol. Eng.* **2007**, *30*, 103–111, doi:10.1016/j.ecoleng.2006.07.001.
84. Raisin, G.; Mitchell, D.; Croome, R. The effectiveness of a small constructed wetland in ameliorating diffuse nutrient loadings from an Australian rural catchment. *Ecol. Eng.* **1997**, *9*, 19–35, doi:10.1016/s0925-8574(97)00016-5.
85. Lu, S.; Wu, F.; Lu, Y.; Xiang, C.; Zhang, P.; Jin, C. Phosphorus removal from agricultural runoff by constructed wetland. *Ecol. Eng.* **2009**, *35*, 402–409, doi:10.1016/j.ecoleng.2008.10.002.
86. Maillard, E.; Payraudeau, S.; Faivre, E.; Grégoire, C.; Gangloff, S.; Imfeld, G. Removal of pesticide mixtures in a stormwater wetland collecting runoff from a vineyard catchment. *Sci. Total Environ.* **2011**, *409*, 2317–2324, doi:10.1016/j.scitotenv.2011.01.057.
87. Obarska, P.; Ozimek, T. Comparison of usefulness of three emergent macrophytes for surface water protection against pollution and eutrophication: Case study, Bielkowo, Poland. In Proceedings of the 4th Workshop on Nutrient Cycling and Retention in Natural and Constructed Wetlands, Trebon, Czech Republic, 26–29 September 2001.
88. Forbes, E.G.A.; Foy, R.H.; Mulholland, M.V.; Brettell, J.L. Performance of a constructed wetland for treating farm-yard dirty water. *Water Sci. Technol.* **2011**, *64*, 22–28, doi:10.2166/wst.2011.584.
89. Maniquiz, M.C.; Lee, S.Y.; Choi, J.Y.; Jeong, S.M.; Kim, L.H. Treatment performance of a constructed wetland during storm and non-storm events in Korea. *Water Sci. Technol.* **2012**, *65*, 119–126, doi:10.2166/wst.2011.843.
90. Kivaisi, A.K. The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. *Ecol. Eng.* **2001**, *16*, 545–560, doi: 10.1016/S0925-8574(00)00113-0.
91. Díaz, F.J.; O'geen, A.T.; Dahlgren, R.A. Agricultural pollutant removal by constructed wetlands: Implications for water management and design. *Agric. Water Manag.* **2012**, *104*, 171–183, doi:10.1016/j.agwat.2011.12.012.
92. Koskiahio, J.; Ekholm, P.; Rätty, M.; Riihimäki, J.; Puustinen, M. Retaining agricultural nutrients in constructed wetlands—Experiences under boreal conditions. *Ecol. Eng.* **2003**, *20*, 89–103, doi:10.1016/s0925-8574(03)00006-5.
93. Sovik, A.K.; Klove, B. Emission of N₂O and CH₄ from a constructed wetland in southeastern Norway. *Sci. Total Environ.* **2007**, *380*, 28–37, doi:10.1016/j.scitotenv.2006.10.007.
94. Johannesson, K.M.; Andersson, J.L.; Tonderski, K.S. Efficiency of a constructed wetland for retention of sediment-associated phosphorus. *Hydrobiologia* **2011**, *674*, 179–190, doi:10.1007/s10750-011-0728-y.
95. Stentström, T.; Carlander, A. Occurrence and die-off of indicator organisms in the sediment in two constructed wetlands. *Water Sci. Technol.* **2001**, *44*, 223–230.
96. Vymazal, J. Emergent plants used in free water surface constructed wetlands: A review. *Ecol. Eng.* **2013**, *61*, 582–592, doi:10.1016/j.ecoleng.2013.06.023.
97. Wu, H.; Zhang, J.; Li, P.; Zhang, J.; Xie, H.; Zhang, B. Nutrient removal in constructed microcosm wetlands for treating polluted river water in northern China. *Ecol. Eng.* **2011**, *37*, 560–568, doi:10.1016/j.ecoleng.2010.11.020.
98. Jamshidi, S.; Akbarzadeh, A.; Woo, K.-S.; Valipour, A. Wastewater treatment using integrated anaerobic baffled reactor and bio-rack wetland planted with *Phragmites* sp. and *Typha* sp. *J. Environ. Health Sci. Eng.* **2014**, *12*, 1–12, doi:10.1186/s40201-014-0131-5.
99. Weragoda, S.K.; Jinadasa, K.B.S.N.; Zhang, D.Q.; Gersberg, R.M.; Tan, S.K.; Tanaka, N.; Jern, N.W. Tropical application of floating treatment wetlands. *Wetlands* **2012**, *32*, 955–961, doi:10.1007/s13157-012-0333-5.
100. Jinadasa, K.B.S.N.; Tanaka, N.; Sasikala, S.; Werellagama, D.R.I.B.; Mowjood, M.I.M.; Ng, W.J. Impact of harvesting on constructed wetlands performance—A comparison between *Scirpus grossus* and *Typha angustifolia*. *J. Environ. Sci. Health Part A* **2008**, *43*, 664–671, doi:10.1080/10934520801893808.
101. White, S.A.; Cousins, M.M. Floating treatment wetland aided remediation of nitrogen and phosphorus from simulated stormwater runoff. *Ecol. Eng.* **2013**, *61*, 207–215, doi:10.1016/j.ecoleng.2013.09.020.
102. Chang, N.-B.; Xuan, Z.; Marimon, Z.; Islam, K.; Wanielista, M.P. Exploring hydrobiogeochemical processes of floating treatment wetlands in a subtropical stormwater wet detention pond. *Ecol. Eng.* **2013**, *54*, 66–76, doi:10.1016/j.ecoleng.2013.01.019.
103. Sim, C.H.; Eikaas, H.S.; Chan, S.H.; Gan, J. Nutrient removal and plant biomass of 5 wetland plant species in Singapore. *Water Pract. Technol.* **2011**, *6*, 1–2, doi:10.2166/wpt.2011.053.
104. Shelef, O.; Gross, A.; Rachmilevitch, S. Role of plants in a constructed wetland: Current and new perspectives. *Water* **2013**, *5*, 405–419, doi:10.3390/w5020405.

105. Hernández-Crespo, C.; Oliver, N.; Bixquert, J.; Gargallo, S.; Martin, M.A. Comparison of three plants in a surface flow constructed wetland treating eutrophic water in a Mediterranean climate. *Hydrobiologia* **2015**, *774*, 183–192, doi:10.1007/s10750-015-2493-9.
106. Yousefi, Z.; Mohseni-Bandpei, A. Nitrogen and phosphorus removal from wastewater by subsurface wetlands planted with *Iris pseudacorus*. *Ecol. Eng.* **2010**, *36*, 777–782, doi:10.1016/j.ecoleng.2010.02.002.
107. Sung, K.; Lee, G.J.; Munster, C. Effects of *Eichhornia crassipes* and *Ceratophyllum demersum* on soil and water environments and nutrient removal in wetland microcosms. *Int. J. Phytoremediation* **2015**, *17*, 936–944.
108. Gu, B. Environmental conditions and phosphorus removal in Florida lakes and wetlands inhabited by *Hydrilla verticillata* (Royle): Implications for invasive species management. *Biol. Invasions* **2006**, *8*, 1569–1578, doi:10.1007/s10530-005-5851-0.
109. Upadhyay, A.K.; Bankoti, N.; Rai, U. Studies on sustainability of simulated constructed wetland system for treatment of urban waste: Design and operation. *J. Environ. Manag.* **2016**, *169*, 285–292, doi:10.1016/j.jenvman.2016.01.004.
110. Xing, X.; Ding, S.; Liu, L.; Chen, M.; Yan, W.; Zhao, L.; Zhang, C. Direct evidence for the enhanced acquisition of phosphorus in the rhizosphere of aquatic plants: A case study on *Vallisneria spiralis*. *Sci. Total Environ.* **2018**, *616*, 386–396, doi:10.1016/j.scitotenv.2017.10.304.
111. Jin, S.-Q.; Zhou, J.-B.; Bao, W.-H.; Chen, J.; Li, D.-D.; Li, Y. Comparison of nitrogen and phosphorus uptake and water purification ability of five submerged macrophytes. *Environ. Sci.* **2017**, *38*, 156–161.
112. Iatrou, E.I.; Stasinakis, A.S.; Aloupi, M. Cultivating duckweed *Lemna minor* in urine and treated domestic wastewater for simultaneous biomass production and removal of nutrients and antimicrobials. *Ecol. Eng.* **2015**, *84*, 632–639, doi:10.1016/j.ecoleng.2015.09.071.
113. Zhou, X.; Li, Z.; Zhao, R.; Gao, R.; Yun, Y.; Saino, M.; Wang, X. Experimental comparisons of three submerged plants for reclaimed water purification through nutrient removal. *Desalination Water Treat.* **2015**, *57*, 1–10, doi:10.1080/19443994.2015.1048736.
114. Kumari, M.; Tripathi, B.D. Effect of aeration and mixed culture of *Eichhornia crassipes* and *Salvinia natans* on removal of wastewater pollutants. *Ecol. Eng.* **2014**, *62*, 48–53, doi:10.1016/j.ecoleng.2013.10.007.
115. Wu, X.; Yang, X.-E.; Li, T.-Q.; Fang, Y.-Y. Study on purified efficiency of phosphorus and nitrogen from eutrophicated sight water by several floating macrophytes. *J. Soil Water Conserv.* **2007**, *5*, 128–132.
116. Lu, X.M.; Lu, P.Z.; Chen, J.J. Nitrogen and phosphorus removal and morphological and physiological response in *Nymphaea tetragona* under various planting densities. *Toxicol. Environ. Chem.* **2012**, *94*, 1319–1330.
117. Tian, K.; Liu, G.; Xiao, D.; Sun, J.; Lu, M.; Huang, Y.; Lin, P. Ecological effects of dam impoundment on closed and half-closed wetlands in China. *Wetlands* **2015**, *35*, 889–898, doi:10.1007/s13157-015-0679-6.
118. Tripathi, B.D.; Srivastava, J.; Misra, K. Nitrogen and phosphorus removal-capacity of four chosen aquatic macrophytes in tropical freshwater ponds. *Environ. Conserv.* **1991**, *18*, 143–147, doi:10.1017/s037689290002172x.
119. Zhao, F.; Xi, S.; Yang, X.; Yang, W.; Li, J.; Gu, B.; He, Z. Purifying eutrophic river waters with integrated floating island systems. *Ecol. Eng.* **2012**, *40*, 53–60, doi:10.1016/j.ecoleng.2011.12.012.
120. Greenway, M. Suitability of macrophytes for nutrient removal from surface flow constructed wetlands receiving secondary treated sewage effluent in Queensland, Australia. *Water Sci. Technol.* **2003**, *48*, 121–128, doi:10.2166/wst.2003.0101.
121. Marion, L.C.; Paillisson, J.-M. A mass balance assessment of the contribution of floating-leaved macrophytes in nutrient stocks in an eutrophic macrophyte-dominated lake. *Aquat. Bot.* **2003**, *75*, 249–260.
122. Yan, Y.; Xu, J. Improving winter performance of constructed wetlands for wastewater treatment in northern China: A review. *Wetlands* **2014**, *34*, 243–253, doi:10.1007/s13157-013-0444-7.
123. Dai, F.; Lee, C.; Zhang, X. GIS-based geo-environmental evaluation for urban land-use planning: A case study. *Eng. Geol.* **2001**, *61*, 257–271, doi:10.1016/s0013-7952(01)00028-x.
124. Baker, C.; Lawrence, R.; Montagne, C.; Patten, D. Mapping wetlands and riparian areas using landsat ETM+ imagery and decision-tree-based models. *Wetlands* **2006**, *26*, 465–474.
125. Junk, W.J.; An, S.; Finlayson, C.M.; Gopal, B.; Květ, J.; Mitchell, S.A.; Mitsch, W.J.; Robarts, R.D. Current state of knowledge regarding the world's wetlands and their future under global climate change: A synthesis. *Aquat. Sci.* **2012**, *75*, 151–167, doi:10.1007/s00027-012-0278-z.
126. Min, K.; Kang, H.; Lee, D. Effects of ammonium and nitrate additions on carbon mineralization in wetland soils. *Soil Biol. Biochem.* **2011**, *43*, 2461–2469, doi:10.1016/j.soilbio.2011.08.019.
127. Sims, A.; Zhang, Y.; Gajaraj, S.; Brown, P.B.; Hu, Z. Toward the development of microbial indicators for wetland assessment. *Water Res.* **2013**, *47*, 1711–1725, doi:10.1016/j.watres.2013.01.023.
128. Chen, L.; Yang, X.; Chen, L. Environmental assessment of land use planning based on remote-sensing technique and geographic information system in Zoucheng County. In Proceedings of the International Conference on Biology, Environment and Chemistry (ICBEC), Hong Kong, China, 28–30 December 2010.
129. Reif, M.; Frohn, R.C.; Lane, C.R.; Autrey, B. Mapping isolated wetlands in a karst landscape: GIS and remote sensing methods. *GISci. Remote Sens.* **2009**, *46*, 187–211, doi:10.2747/1548-1603.46.2.187.
130. Moreno-Mateos, D.; Mander, U.; Pedrocchi, C. Optimal location of created and restored wetlands in mediterranean agricultural catchments. *Water Resour. Manag.* **2010**, *24*, 2485–2499, doi:10.1007/s11269-009-9564-5.
131. Sabokrouhiyeh, N.; Bottacin-Busolin, A.; Nepf, H.; Marion, A. Effects of vegetation density and wetland aspect ratio variation on hydraulic efficiency of wetlands. *Found. Convect. Density Stratif.* **2016**, 101–113, doi:10.1007/978-3-319-27750-9_9.

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132. Wu, H.; Zhang, J.; Ngo, H.H.; Guo, W.; Shuang, L.; Liang, S.; Fan, J.; Liu, H. A review on the sustainability of constructed wetlands for wastewater treatment: Design and operation. *Bioresour. Technol.* **2015**, *175*, 594–601, doi:10.1016/j.biortech.2014.10.068.
 133. Lu, S.; Zhang, X.; Wang, J.; Pei, L. Impacts of different media on constructed wetlands for rural household sewage treatment. *J. Clean. Prod.* **2016**, *127*, 325–330, doi:10.1016/j.jclepro.2016.03.166.
 134. Joan, G.; Aguirre, P.; Mujeriego, R.; Huang, Y.; Ortiz, L.; Bayona, J.M. Initial contaminant removal performance factors in horizontal flow reed beds used for treating urban wastewater. *Water Res.* **2004**, *38*, 1669–1678, doi:10.1016/j.watres.2004.01.011.
 135. Seo, D.C.; Cho, J.S.; Lee, H.J.; Heo, J.S. Phosphorus retention capacity of filter media for estimating the longevity of constructed wetland. *Water Res.* **2005**, *39*, 2445–2457.
 136. Gustafsson, J.P.; Renman, A.; Renman, G.; Poll, K. Phosphate removal by mineral-based sorbents used in filters for small-scale wastewater treatment. *Water Res.* **2008**, *42*, 189–197, doi:10.1016/j.watres.2007.06.058.
 137. Martin, L.; Margit, K.I.; Ulo, M.; Riho, M.T.; Christina, V.; Kalle, K.T. Active filtration of phosphorus on Ca-rich hydrated oil shale ash: Does longer retention time improve the process? *Environ. Sci. Technol.* **2009**, *43*, 3809–3814.
 138. Early, R.; Bradley, B.A.; Dukes, J.S.; Lawler, J.J.; Olden, J.D.; Blumenthal, D.M.; Gonzalez, P.; Grosholz, E.D.; Ibañez, I.; Miller, L.P.; et al. Global threats from invasive alien species in the twenty-first century and national response capacities. *Nat. Commun.* **2016**, *7*, 12485, doi:10.1038/ncomms12485.
 139. Song, H.-L.; Nakano, K.; Taniguchi, T.; Nomura, M.; Nishimura, O. Estrogen removal from treated municipal effluent in small-scale constructed wetland with different depth. *Bioresour. Technol.* **2009**, *100*, 2945–2951, doi:10.1016/j.biortech.2009.01.045.
 140. García, J.; Aguirre, P.; Barragán, J.; Mujeriego, R.; Matamoros, V.; Bayona, J.M. Effect of key design parameters on the efficiency of horizontal subsurface flow constructed wetlands. *Ecol. Eng.* **2005**, *25*, 405–418, doi:10.1016/j.ecoleng.2005.06.010.
 141. Crites, R.W. Design criteria and practice for constructed wetlands. *Water Sci. Technol.* **1994**, *29*, 1–6, doi:10.2166/wst.1994.0144.
 142. Jenkins, G.A.; Greenway, M. The hydraulic efficiency of fringing versus banded vegetation in constructed wetlands. *Ecol. Eng.* **2005**, *25*, 61–72, doi:10.1016/j.ecoleng.2005.03.001.
 143. Liu, J.; Kattel, G.R.; Arp, H.P.H.; Yang, H. Towards threshold-based management of freshwater ecosystems in the context of climate change. *Ecol. Model.* **2015**, *318*, 265–274, doi:10.1016/j.ecolmodel.2014.09.010.